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Improvement of postural control in individuals with multiple sclerosis after a single-session of ball throwing exercise☆

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ABSTRACT

Background: Deficit in balance control is a common and often an initial disabling symptom of multiple sclerosis (MS). We investigated the role of short-term training in improvement of anticipatory postural adjustments (APAs) and its effect on subsequent control of posture in individuals with MS.

Methods: A pre-post feasibility study involved eight individuals with relapsing-remitting MS who participated in the laboratory tests before and after a single training session consisting of throwing a medicine ball. The outcome measures including electromyographic activity of trunk and leg muscles and center of pressure displacements were recorded and analyzed during the anticipatory and compensatory phases of postural control.

Results: The training resulted in enhancement of the generation of APAs seen as significantly earlier onset of leg and trunk muscle activity prior to the bilateral arm flexion task ($p < 0.05$). Significantly early activation of postural muscles was also observed prior to the predictable external perturbation, the task that was not a part of training, indicating the transfer of the effect of the single training session. Postural control during the balance restoration phase was improved after training ($p < 0.05$).

Conclusion: The observed training-related improvements of balance control suggest that focused rehabilitation could be effective in improving postural control. Consequentially, this could enhance mobility and quality of life in the individuals with MS.

1. Introduction

Postural imbalance is one of the initial disabling symptoms of multiple sclerosis (MS) that is often reported in persons with low level of disability (Cameron and Lord, 2010; Findling et al., 2011; Fling et al., 2014; Ganesan et al., 2015; Kanekar and Aruin, 2013; Martin et al., 2006; Peebles et al., 2016). Poor balance control is a significant contributing factor to the increased risk of falling in individuals with MS (Cameron and Lord, 2010; Cattaneo et al., 2002; Finlayson et al., 2006; Kasser et al., 2011; Matsuda et al., 2011; Sosnoff et al., 2011) and is also associated with lower engagement in physical activity (Motl et al., 2006).

The stability of human vertical posture is affected by the high location of the center of mass (COM), small support area, and multiple joints between the feet and the center of mass. Moreover, when a standing person performs a quick movement or interacts with external objects, the mechanical coupling of body segments leads to postural perturbations that may create a situation when balance is jeopardized. While maintaining vertical posture, the central nervous system (CNS) uses two main types of adjustments in the activity of the trunk and leg muscles when dealing with body perturbations. Anticipatory postural adjustments (APAs) control the position of the COM of the body by activating the trunk and leg muscles *prior* to a forthcoming body perturbation, thus minimizing the danger of losing equilibrium (Massion, 1992). Compensatory postural adjustments (CPAs) are initiated by the sensory feedback signals and serve as a mechanism of restoration of the position of the COM *after* a perturbation has already occurred (Alexandrov et al., 2005).

APAs are an essential mechanism of balance control that ensures adequate postural preparation prior to task performance or in dealing with the external environment. Several studies focused on the investigation of APAs revealed that individuals with MS, have impaired APAs with smaller magnitudes of anticipatory muscle activation (Krishnan et al., 2012b), delayed anticipatory onsets of muscle activity (Krishnan et al., 2012a, 2012b), smaller anticipatory center of pressure (COP) displacements (Aruin et al., 2015a), and diminished ability to produce directional specific patterns of anticipatory electromyographic activity (EMG) (Krishnan et al., 2012a) compared to control subjects.

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Table 1
Demographics and clinical characteristics of the participants.

Variable	
Gender (male, female)	3, 5
Age (years)	46.25 ± 10.58
Weight (kg)	71.10 ± 11.00
Height (cm)	170.89 ± 15.00
Disease duration (years)	9.88 ± 5.19
EDSS score	3.31 ± 0.37
MMSE score	29.00 ± 0.93
ABC score	85.63 ± 4.14
BBS	48.63 ± 2.72

Values are mean ± standard deviation. EDSS (*Expanded Disability Status Scale), 0–10 points,* MMSE (Mini-Mental State Examination), 0–30 points; ABC (Activities-specific Balance Confidence), 0–100%; BBS (Berg Balance Scale), 0–56 points.

Inability of the individuals with MS to generate optimal postural adjustments prior to an upcoming balance threat resulted in larger compensatory muscle activation and greater COP displacements during the balance restoration phase (Aruin et al., 2015a) putting them at a greater risk of losing balance. Yet, in clinical practice, a large percentage of individuals with MS requiring balance rehabilitation are treated with conventional rehabilitation approaches (Cattaneo et al., 2007; Nilsagard et al., 2014; Paltamaa et al., 2012) that are mainly focus on enhancement of compensatory postural adjustments. Given the important role of APAs in balance control, it is likely that training-related improvements in APAs could lead to greater postural stability. However, no prior studies investigating the effect of APA-focused training in enhancement of balance control in individuals with MS were conducted.

This study was thus aimed at investigating the feasibility of APA-focused training involving throwing a ball in enhancing balance control of individuals with MS. We hypothesized that with training, early onset of anticipatory muscle activity will be observed prior to a self-initiated perturbation induced by lifting the arms. This enhanced postural preparation will result in reduced COP peak displacements following the perturbation, indicating greater postural stability. We also hypothesized that there will be a transfer of the improvements achieved with the APA-focused training seen as early activation of postural muscles prior to the external perturbations.

2. Materials and methods

2.1. Participants

Eight individuals with relapsing – remitting MS (3 males and 5 females) participated in the study. Descriptive characteristics of the participants are shown in Table 1. The inclusion criteria were: normal or corrected to normal vision, an Expanded Disability Status Scale (EDSS) (Kurtzke, 1983) score of 4 or less, and the ability to stand independently without any aid or orthosis for at least 3 min. Subjects were excluded if they had a history of shoulder subluxation or dislocation, other medical illnesses, pain that interfered with their daily activities, or if they were unable to perform the experimental tasks. The Functional Status Scale (FSS) score for the group was 1.87 ± 0.64 (Kurtzke, 1983). Based on self-reported fall history during the past 12 months, three individuals with MS had a history of falls. The study was approved by the Institutional Review Board of the University of Illinois at Chicago and written informed consent was obtained from each subject.

2.2. Experimental setup and procedure

Subjects were tested twice, before (pre-training) and immediately after a single training session (post-training), using predictable self-initiated and externally induced perturbations (Fig. 1). Self-initiated perturbations were induced by bilateral shoulder flexion (Krishnan et al., 2012a). The subjects were asked to stand with their arms hanging loosely by their sides, with the palms oriented toward the body. They were instructed to perform the movements "as fast as possible", to stop at the final position and to return back. Externally induced perturbations were created by the pendulum impact paradigm. The subjects were positioned in front of an aluminum pendulum

attached to the ceiling. Each participant received the pendulum impact with their hands, while their arms, wrists, and fingers were extended at the shoulder level (Aruin et al., 2015a). All the trials of the pendulum release were implemented by the same experimenter. During the tests, the subjects were instructed to maintain upright stance while standing barefoot on the force platform with their feet shoulder width apart. Two to three practice trials were given prior to each test. Five trials of 5 s in duration were performed for each task, and the order of tests was randomized across the subjects.

2.3. Training

The training session consisted of 120 repetitions of throwing a medicine ball (3 sets of 40 repetitions with a 2-min rest between the sets) and it was administered by a physical therapist. The subjects stood with feet shoulder width apart and were required to throw the ball in a self-passed manner. After they threw the ball towards the therapist, a research assistant took the ball from the therapist and passed it to the subject before he/she threw it towards the physical therapist again. The medicine ball was put in motion at the shoulder level toward the physical therapist positioned at a 3-m distance. During each set the subject was instructed to throw the ball from either the subjects' midline or approximately 30° to the right of left of midline in blocks of 10–15 throws and the order of blocks was randomized. The subjects were aware of the number of throws in each set. A 0.9 or 1.8 kg medicine ball was used for subjects weighing below or above 55 kg, respectively (Aruin et al., 2015b). Throughout the training session a

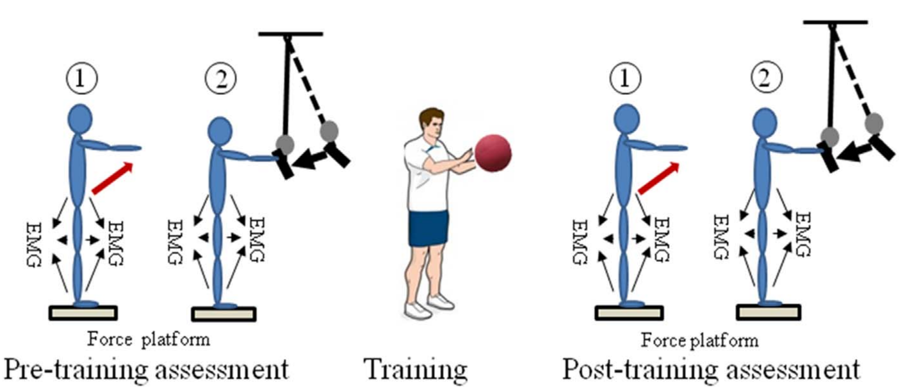

Fig. 1. Schematic representation of the experimental setup. Self-initiated perturbations (1- bilateral shoulder flexion) and external perturbations (2- pendulum impact) were used for the pre- and post-training assessment. EMG activity and ground reaction forces were recorded. Training involved throwing a medicine ball.